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Constraints on Parton Distribution from CDF

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The asymmetry in $W^- - W^+$ production in $p\overline{p}$ collisions and Drell-Yan data place tight constraints on parton distributions functions. The W asymmetry data constrain the slope of the quark distribution ratio d(x)/u(x) in the x range 0.007-0.27. The published W asymmetry results from the CDF 1992-3 data ($\approx$ 20 pb^{-1}) greatly reduce the systematic error originating from the choice of PDF's in the W mass measurement at CDF. These published results have also been included in the CTEQ3, MRSA, and GRV94 parton distribution fits. These modern parton distribution functions are still in good agreement with the new 1993-94 CDF data($\approx$ 108 $pb^{-1} combined$). Preliminary results from CDF for the Drell-Yan cross section in the mass range 11-350 GeV/c^2 are discussed.

1 W Asymmetry

Typically PDF's are extracted from deep inelastic scattering (DIS) cross sections for eN, μN and νN as a function of x and Q^2. In particular, the ratio of d and u quark distributions is extracted from the ratio of μ (or e) scattering from neutrons and protons. Such data, however, suffer from uncertainties in neutron binding corrections (e.g., shadowing corrections and Fermi motion effects) and higher twist and nonperturbative contributions at low Q^2. These corrections become important when the structure functions are evolved to $Q^2 = M_W^2$.

At Tevatron energies, W bosons are produced primarily through quark anti-quark annihilations. In leading order QCD the W production cross section is proportional to the product of parton density functions:

$$\sigma_W \sim u(x)d(x), \tag{1}$$

at $x = \frac{M_W}{\sqrt{s}}e^{\pm y}$ and $Q^2 = M_W^2$. Here y is the rapidity of the final state W.

High statistics W charge asymmetry measurements at the Tevatron $\overline{p}p$ collider provide new information that significantly constrains the u and d quark distributions, specifically the slope of the $d(x)/u(x)$ ratio in the x range 0.007 to 0.27.

$$\begin{aligned} A(y_W) &\equiv \frac{d\sigma_W^+(y)/dy_W - d\sigma_W^-(y)/dy_W}{d\sigma_W^+(y)/dy_W + d\sigma_W^-(y)/dy_W}, \\ A(y_W) &\simeq \frac{u_1d_2 - u_2d_1}{u_1d_2 + u_2d_1} = \frac{d_2/u_2 - d_1/u_1}{d_2/u_2 + d_1/u_1} \end{aligned} \tag{2}$$

Thus, $A(y_W)$ is related to the difference in d/u between x_1 of the parton from the proton and x_2 of the parton from the anti-proton expressed as:

$$x_{1,2} = \frac{M_W}{\sqrt{s}}e^{\pm y.} \tag{3}$$

The W decay involves a final state neutrino. The lepton charge asymmetry $A(y_l)$, is defined as:

$$A(y_l) = \frac{dN_+(y_l)/dy_l - dN_-(y_l)/dy_l}{dN_+(y_l)/dy_l + dN_-(y_l)/dy_l}, \tag{4}$$

where $N_\pm$ are observed numbers of leptons as a function of lepton pseudorapidity y_l. Thus, the slope of d/u ratio, at low x and Q^2=M_W^2, is related to the lepton charge asymmetry from W decays modified by the well-understood $V - A$ decay of W bosons to leptons.

When comparing the experimental measurement with the theory predictions, the significant dependence of the lepton charge asymmetry on the final state lepton E_t cut (and the weaker dependence on missing E_t cut) must be taken into account. The CDF asymmetry analysis makes use of both $W \rightarrow e\nu$ and $\mu\nu$ events. These events are selected by requiring that the e's and μ's be isolated, identified, and well tracked. In addition, the leptons must have transverse energy $E_T > 25$ GeV. The missing transverse energy $\not{E}_T$ of the event in the calorimeter and muon system must be > 25 GeV. In order to suppress QCD backgrounds, events including a jet with $E_T > 20$ GeV are rejected. The acceptance and efficiencies for detecting l^+ and l^- are equal, and the charge asymmetry $A(\eta)$ reduces to the difference in the number of l^+ and l^- over the sum of the two. Since CP invariance implies $A(+\eta) = -A(-\eta)$, the data at $-\eta$ are combined with that at $+\eta$ to increase the statistics in each η bin. The CDF asymmetry measurement is robust because the systematic errors are negligible relative to statistical errors and corrections to the raw measurement are small (5% or less).

The CDF collaboration published a W charge asymmetry study using its 1992-93 run 1A data ($\approx$ 20 pb^{-1}). This asymmetry measurement was used to distinguish between various PDF parametrizations and place tight constraints on these distributions. These earlier CDF results favored the MRS fits over the CTEQ2 PDF's.

Table 1: CDF data includes 1992-93 central and plug detectors ($\approx 20\ pb^{-1}$), and 1993-94 central detector data sets ($\approx 88\ pb^{-1}$). The results of the deviation from 1.0 of weighted ratio R of data to theory comparisons for various recent PDF's. The weighted ratio are sensitive to the difference in the overall level predicted by each PDF. The MRSA,G, CTEQ3M, and GRV94 (*) included the CDF 1992-1993 data in their global fits.

	$\overline{R}(y)$ $0.0 < \lvert y\rvert < 2.0$	
PDF Set	$\Delta\sigma$	$\mathcal{P}(\sigma^2)$
CTEQ 3M*	-0.7	0.517
CTEQ 2M	8.3	< 0.001
CTEQ 2MS	4.7	< 0.001
CTEQ 2MF	6.5	< 0.001
CTEQ 2ML	6.1	< 0.001
MRS A,G*	0.2	0.857
MRS H	-1.8	0.081
MRS D'_-	-0.6	0.579
MRS D'_0	-3.5	< 0.001
GRV94*	1.2	0.244
GRV92	2.8	0.005

In this communication, the W production charge asymmetry analysis of both the 1992-93 data, and the first $\approx 88\ pb^{-1}$ of data from the 1994-95 run [in the central detector region($|\eta| < 1.1$)] is presented. The larger statistical sample of the combined data ($\approx 108\ pb^{-1}$) is a factor of 5 larger (in the central detector region) relative to the 1992-93 analysis. Theoretical values for $A(\eta)$ have been calculated using the DYRAD program which employs next to leading order (NLO) QCD partonic cross section calculation. Several NLO parton distribution functions and the well-known purely leptonic V-A decay of the W are used as input. Experimental cuts and detector effects are also included in the calculations, To quantify the discriminating power of the data against each of the various predictions, Table 1 shows the χ^2 test of the error weighted ratio of the nine data points to theory (i.e. the deviation of average ratio from 1.0) against the predictions of various PDF's.

By restricting the shape of the PDF's, the W asymmetry measurement has significantly reduced the systematic uncertainty in the W mass measurement. The W mass fits depend on the choice of PDF parametrizations, which in turn are constrained by the W production charge asymmetry data. The dependence of the fitted W mass on the choice of PDF's is strongly correlated with the corresponding predictions of the PDF's for the W charge asymmetry. The published 1992-93 CDF W asymmetry results have been used as a guide in reducing the uncertainty due to the choice of PDF parametrizations used in the W mass analysis. The 1992-93 asymmetry measurement thus allowed CDF to reduce systematic uncertainty on M_W due to PDF's from 100 MeV, if only DIS data are used, to 50 MeV (2σ error), when the W asymmetry constraints (based on $\approx 20\ pb^{-1}$ of data) are included. It is expected that the use of the $\approx 108\ pb^{-1}$ from the combined 1992-94 data (and the $\approx 150\ pb^{-1}$ total sample expected by middle of 1996) would yield a further reduction in the errors.

2 CDF Preliminary Measurement of Drell-Yan production

Drell-Yan events are easily reconstructed from the measured properties of the two final state leptons. The differential Drell-Yan cross section provides information on the magnitude of the quark distributions in the x range 0.006-0.03 over a Q^2 range of 121-12000 GeV^2. The CDF collaboration has published the differential cross section $d^2\sigma/dMdy_{|y|<1}$, over the mass range $11 < M < 150\ GeV/c^2$ using dielectron and dimuon data from the 1988-89 collider run ($\approx 4\ pb^{-1}$). The results showed $1/M^3$ dependence as expected from the naive Drell-Yan model. The measurement was consistent with those distributions having the largest quark contribution in the x interval 0.006 to 0.03, particularly the distributions which incorporated the most recent DIS data. However, as was the case for the very early 1988-89 W asymmetry data, the statistics were limited.

A preliminary Drell-Yan cross section measurements using a sample of high mass ($M > 30GeV/c^2$) dielectron and dimuon events collected during the 1992-93 run($\approx 20\ pb^{-1}$) and a sample of very high mass ($E_T > 150GeV/c^2$ dimuon events collected during the combined 1992-1994 runs ($\approx 70\ pb^{-1}$) are compared to theory in Figure 1.

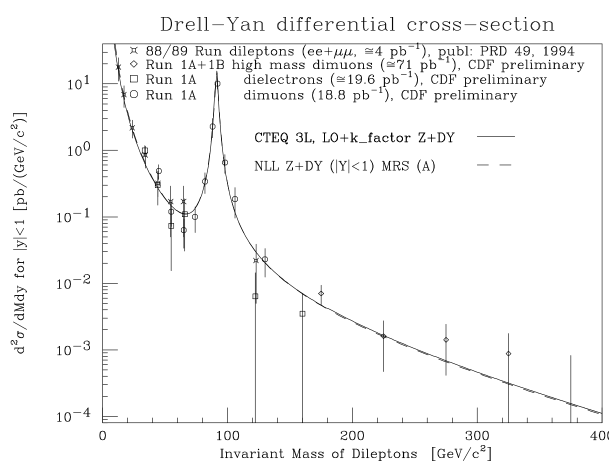

Figure 1: These preliminary dilepton results indicate good agreement with both the LO (including a K factor) calculation of the Drell-Yan cross section (including the Z contribution) using modern LO parton distributions (e.g CTEQ3L) [There is also good agreement with a NLO Drell-Yan calculatio using NLO parton distributions (CTEQ3M or MRSA)]. – This paper is to be published in Proceedings of EPS-95, Brussels, 1995–